CONSORTIUM OF AMATEUR RADIO EXPERIMENTERS

A

1.2 GHz.

Repeater
Project

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by:

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Rev 11/93

A 1.2 GHz Home Brew Repeater

Recently, there has been a renewed interest in the 1.2 GHz. band, especially for FM enthusiasts. The need for repeaters has been met only by Icom and the various expensive 1.2 GHz. repeaters offered by them. This article is an attempt by the author to describe the ideas and construction methods used in building a less expensive 1.2 GHz. repeater utilizing parts and accessories easily obtainable by most amateurs.

The Base Band - VHF Radio

The repeater project described in this article can be divided into four areas: The transverter, the high band transceiver and driver, the power amplifier and final adjustments. The basic concept of this repeater is a VHF high band radio coupled to a 1.2 GHz. transverter. Two 1.2 GHz. power modules are used to obtain 10 to 15 watts output. The building block for this project is the G.E. Mastr Executive II high band mobile transceiver. These particular radios have become readily available because they were recently removed from service by the California Highway Patrol. These were used by the CHP as 250mW "VHF extender" radios that were coupled with Motorola low band MICOR mobile radios. These GE units can be found at swapmeets for $25 to $40 per unit.

These radios have all the R.F. boards (both exciter and receiver) mounted on one side of the chassis. The large circuit boards (extender logic) on the bottom of the chassis are not used and can be removed and discarded. Be sure to unsolder and save the plugs that connect the large circuit boards to the exciter and receiver. The removal of these large boards on the bottom of the chassis leaves ore than adequate room for the two transverter boards to be installed later.

Insert the pins from the circuit boards, through the chassis, into the exciter board and receiver board for wiring. Using an LM317 variable regulator, make a voltage regulator and set the regulated voltage to 10 volts. Be sure to heat sink the tab to the chassis. A 6-32 stud is located in one corner near the front panel for this purpose. (See Figure 1) On the exciter board, pins 2, 5, 6 and 7 are ground. Pin 8 is continuous +10 volts, pin 1 is +10 volts switched (by the PTT relay). Pin 4 is mic hi, pin 9 is "PL" hi and pin 3 is connected to pin 5 on the receiver board. Point to point wiring of these connections to the PTT relay, voltage regulator, repeater controller and receiver board is next.

Some interface is required between the exciter and the "PL" generator and the receiver audio, if tone is to be transmitted. From the sub-audible tone generator, a 10K resistor is placed in series with the audio to pin 9 of the exciter board, with a .1uf capacitor to ground from pin 9. From the receiver audio (pin 1 on the receiver board), a 6.8K resistor is placed in series to pin 4 and a .1uf capacitor to ground from the exciter side of the resistor.

The Receiver

The receiver is very straight forward. After installing the crystal, peak the multiplier chain and insert a strong signal (on channel) at the High Band antenna input and tune the mixer and front end. The audio signal is present on pin 1 of the receiver board connector. Some alignment of the detector coil (T604) may be required for symmetrical audio. This is best done with an audio signal inserted into the RF generator and a scope looking across the audio output. Tune T604 for symmetrical waveform on the scope and maximum audio signal. Note: Be sure to set the receiver on channel first.

The receiver connector pins are:

Pin 1	audio output
Pin 2	(no connection)
Pins 3 & 10	+10volts
Pins 4 & 6	chassis ground
Pin 5	temp. compensator (Tx pin 3)

There is no squelch circuit in the receiver. If the repeater will be operating in "carrier squelch," you will need to build a squelch circuit. There are several ICs on the market that will do the job nicely. This repeater was built to run with "tone squelch" only, so no squelch was added. Instead, a Communications Specialists TS-32 sub-audible tone encoder and decoder was used. To switch the PTT line, the switched output from the tone decoder works well.

The Exciter

The exciter is very basic. Using a multimeter, measure pin 2 of the test socket and peak L101, L102 and dip T101. Now, measure pin 1 and peak T101, T102 and dip T103. Measure pin 3 and peak T103, T104 and dip T105. Measure pin 9 and peak T105 and T106. Measure pin 6 and peak T107 and T108. Now inject an audio signal on the Mic Hi and tune L101 for audio clarity. Inject the sub-audible tone on CG Hi and tune L102 for tone clarity. Listen to the output of the exciter on a monitor and balance tune L101 and L102 for minimum tone intermodulation and distortion. You will find that the exciter will put out too much power (200-300mW) so a simple attenuator T pad is required (1/2 watt, 20 ohms in series with another 20 ohms and 30 ohms to ground on a small PC board).

Consider taking the low-pass filter from the heatsink assembly and mounting it next to the exciter board. Route the exciter output through the filter, then to the attenuator and on to the converter. This last step is not required, but it will reduce spurious signals from the final transmitted signal. The converter is broadband and will allow unwanted signals from the exciter to pass and be amplified.

The Transverter

The transverter used in this project is the SHF 1240K, 1240-1300 MHz. Linear Transmit/Receive Converter and SHF-LO local oscillator, available assembled or in kit form from Down East Microwave. The kit includes all the necessary parts, including the crystal and instructions. If the kit is purchased, the instructions should be carefully read several times, as they are quite vague. Construction techniques are important and care should be taken when soldering the surface-mount components. A magnifying glass is helpful when examining the MMICs to determine the location of the dot or slashed lead that indicates the device's input or output.

The transverter is broadband and stable. If it is assembled properly, there is no tuning required, except to set the crystal on frequency. A low temperature crystal oven will help the stability of the high frequency oscillator, especially if the repeater is to be put in an environment with large temperature changes. A 50 ohm resistor was placed across the converter receiver antenna port on the circuit board to ensure a proper impedance and prevent the high gain first stage from oscillating.

Mount the converter board flat onto the chassis. This will require removing the receiver assembly, drilling out the existing standoffs and drilling four (4) to six (6) holes through the chassis and the converter board. Use caution here. Do not drill through any of the traces and be sure to leave adequate room for washers and nuts. Countersink the holes from the receiver side of the chassis and use flathead 6-32 screws, mounting the flat washers and nuts on the converter board. Routing the +12 volts to the transmit side of the converter and the driver module, outside the chassis and away from the +12 volt wires to the receive side of the converter will reduce "cross talk" between the wires that could cause "de-sense" in repeater operation.

The Driver And Power Amplifier

The Driver and PA stages are RF power modules. The Driver module is a Mitsubishi M67715 that puts out 1 to 1.5 watts. A Mitsubishi M57762 that puts out 10 to 15 watts is used for the Power Amplifier. These parts and their specification sheets can be ordered from RF Parts Co. in San Marcos, California.

The modules mount to the inside of the heatsink assembly. A good quality Teflon coax should be used between the driver and the transverter. From the driver to the PA and from the PA to the transmit antenna connector, small rigid hard-line should be used. Keep in mind when building this that the 1/4 wavelength is 2 1/8 inches and any multiple or fraction of this distance can cause oscillations in the amplifiers. With the use of hard-line and a copper ground plane, soldering the hard-line to the ground plane will help eliminate this problem. As in all UHF projects, lead length is critical and should be kept as short as possible.

Each module requires bypass capacitors on the DC supply pins to prevent low frequency oscillations. If at all possible, these should be surface-mount chip capacitors of the appropriate values. The circuit boards required for the modules are very basic. All that is required are pads to solder the module pins to, with a good ground plane around them. Also important is the quality of the circuit board. A double sided fiberglass board is recommended. Shielded Teflon wire or coax should be used when routing the bias and +12 volts to the power module. Solder the shield to the ground plane and keep the wire lengths short. This will help reduce stray RF coupling from the amplifier to the DC lines.

A separate LM 317 (variable voltage regulator) should be used for each power module and the voltages set as recommended by the specification sheets supplied with the modules. This also will allow the builder to adjust the power levels of each stage. A small resistor, about 5 ohms, should be placed in series with the center conductor of the hard-line between the output of the driver and the input of the PA. This serves to isolate the two stages and prevent feedback.

The output of the PA stage should be routed through small hard-line to a type N connector, being sure to maintain a coaxial type coupling to the connector. At these frequencies, it is very important to maintain impedances. Seemingly small inconsistencies or impedance "bumps" can cost several dB's.

Final Adjustments

A service monitor is the ideal instrument for adjusting audio levels and deviation. Service monitors for 1200 MHz. are rare and VERY expensive. Audio levels and frequencies can be set at the base band radio frequencies (144 MHz.) and the converter oscillator frequency should be set as high up the multiplier chain as possible. If a service monitor cannot be obtained, an oscilloscope can be used to set audio levels and a good quality frequency counter will work for setting the frequencies.

Ancillary Equipment

Eight repeaters were built based on this information and several have been in operation since 1991 without any problems. With the addition of a 12 dB preamp on the receiver, the sensitivity was measure at .1 microvolts for 20 dB quieting. A filter or cavity is required between the receiver and antenna or duplexer for the receiver to work in repeater service. Remember, the transverter is a broad band device and there is no selectivity tuning, so a cavity and/or filter is required.

The link radio utilized at all sites is a 406-420 MHz. Motorola MITREK. These radios are available from C.W. Wolfe Co. At most sites, the antenna used for the repeaters is either the Comet or Diamond triband antenna (144/440/1.2 GHz.) used in conjunction with a triplexer. Repeaters and link radios use a common antenna.

All duplexers used in this project were ordered from TX-RX Systems, Inc. A dual port controller for repeater and link control, model RC-100 by Micro Computer Controls is utilized in all repeater systems. This is a low cost, basic device. You may use a controller of your choice, based upon your budget and needs. A good bandpass filter that is fairly easy to build can be found in the RSGB VHF, UHF MANUAL, page 9.20. This simple 3 pole filter has very sharp skirts (50dB down at 800 MHz.) low insertion loss and low SWR.

Acknowledgments

The establishment of **C.A.R.E.** and construction of the **C.A.R.E.** linked repeater system has truly been a group project with each participant contributing a most important "piece of the puzzle." In particular, I would like to thank:

Bob Boehme, W6RHV. Bob was the first in our group to build the transverter and interface it to the GE base band VHF radio. Without Bob's sincere interest, tenacity, patience and laboratory-grade test equipment, this project would have never been successfully completed. Bob also prototyped a 3 and 5 pole interdigital bandpass filter which was later produced in quantity by Cecil Casillas, WD6FZA.

Brian Kantor, WB6CYT. Brian donated his time and skills assisting me with the radio and controller interface as well as the 420 MHz. link radios.

Stu Hacken, WV6H. Stu assumed the role of project coordinator, researching and procuring the major components, such as the duplexers, preamps, heliax, antennas, controllers and 420 MHz. link radios. Stu also provided access to several sites.

Ed Flynn, WA6YVX and **Jason Lansky, NF6E**. Ed and Jason assisted in various capacities including equipment donations, monetary donations and documentation tasks.

What Is C.A.R.E.?

The Consortium of Amateur Radio Experimenters (**C.A.R.E.**) is a group of amateur radio operators who are dedicated to the experimentation, public service and preservation of the amateur radio spectrum. Individual licensees own and operate several remote base and repeater systems on the 6m, 2m, 222 MHz., 440 MHz. and 1.2 GHz. bands, located throughout Southern California.

G.E. MASTR PIN CONNECTIONS

	XMTR		**RCVR**
1.	+10 Volts (switched)	1.	Audio Out
2.	Ground	2.	(no connection)
3.	Osc Compensator (rx 5)	3.	+10 Volts (continuous)
4.	Mic High	4.	Ground
5.	Ground	5.	Osc Compensator (tx 3)
6.	Ground	6.	Ground
7.	Ground	7.	+10 Volts (Continuous)
8.	+10 Volts (Continuous)		
9.	Sub Audible Tone High		
10.	(no connection)		

MOTOROLA MITREK PIN CONNECTIONS

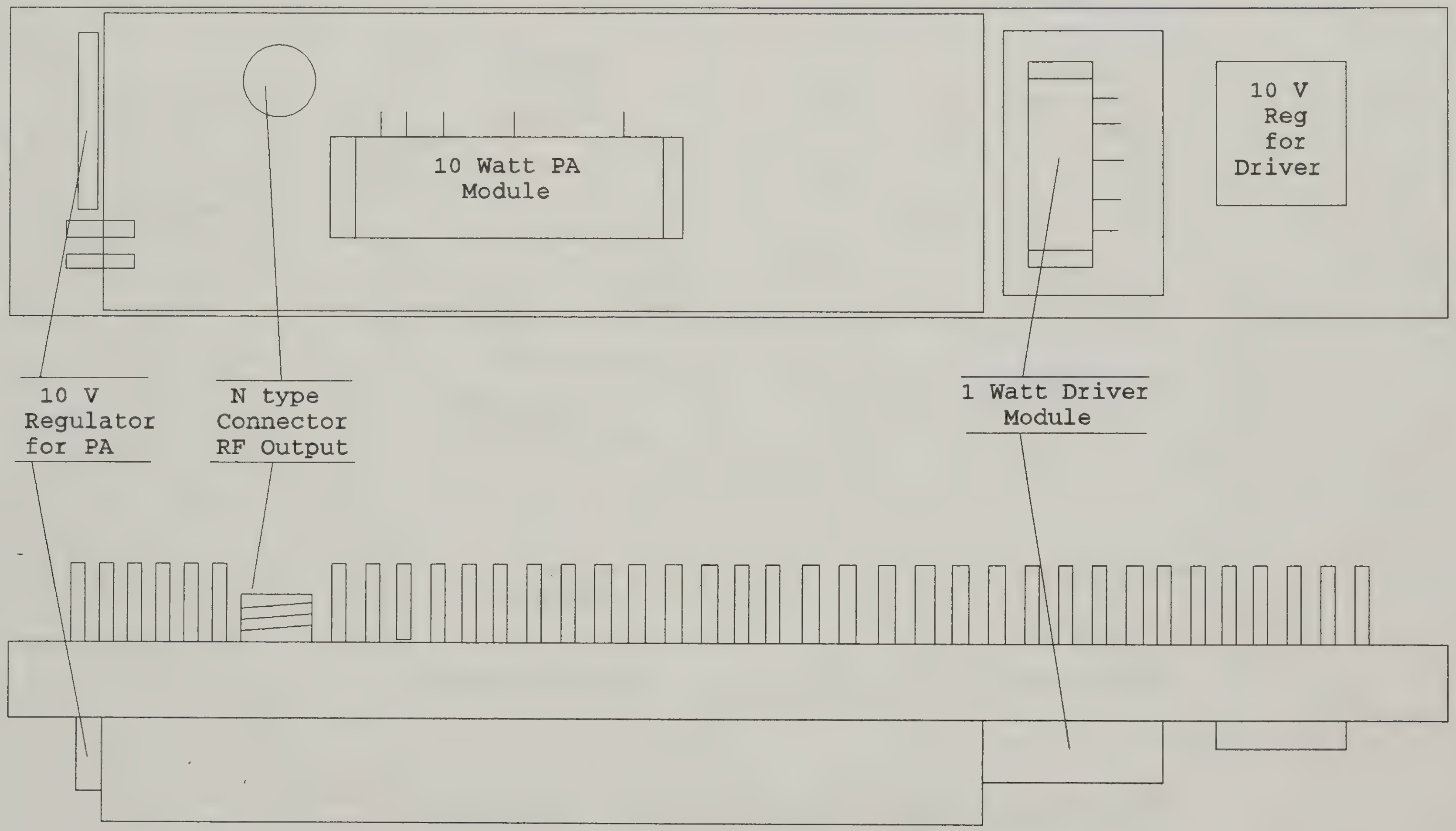
PIN #	PURPOSE
1.	Mic Hi
2.	Mic Lo
3.	Speaker
4.	+12V (Receiver)
5.	Speaker
6.	Ground
7.	Freq 1
8.	Freq 3
9.	Freq 2
10.	Freq 4
11.	Discriminator Audio
12.	+12V (PTT Relay)
13.	PTT (To Ground)
14.	Squelch Pot Wiper
15.	Volume Pot Wiper
16.	P.L. Hang-Up
17.	Ground (Large Pin)
18.	Spare (Large Pin)
19.	+12V (Large Pin)

1.2 GHz. REPEATER

TERMINAL STRIP CONNECTIONS

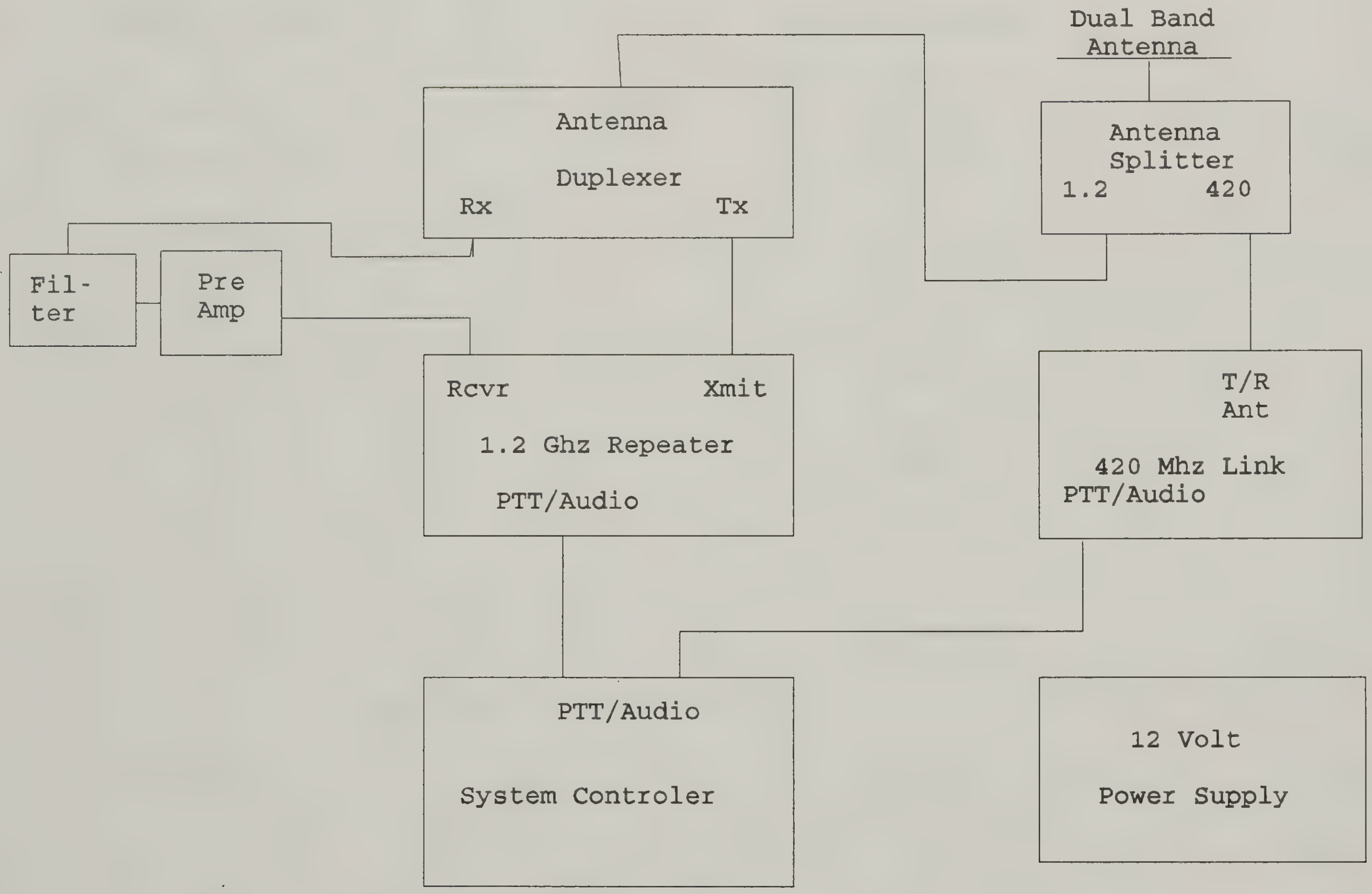
Terminal Screw #	Connector Pin #	Color	Purpose
1	7	Red	+12V Fused
2 (not used)	-	Red	+12V PA Only
3 (not used)	-	Yellow	PTT Enable
4	6	Green	+12V Tx Switched
5	-	Red	+12V Fm Sup/Fuse
6 (not used)	-	Red	+12V Fm Fuse/Sw
7	4	Shld	Rx Audio
8	3	Shld	Tx Audio
9	2	Blue	COS
10	1	Orange	PTT
11	-	Green	N.O. Aux Relay
12	-	Green	N.O. Aux Relay
13	5	Black	Ground (-)
-	8	Brown	Spare

11/93
C.A.R.E. System
1.2 GHz. Repeater
WA6RLV
John W. Austin



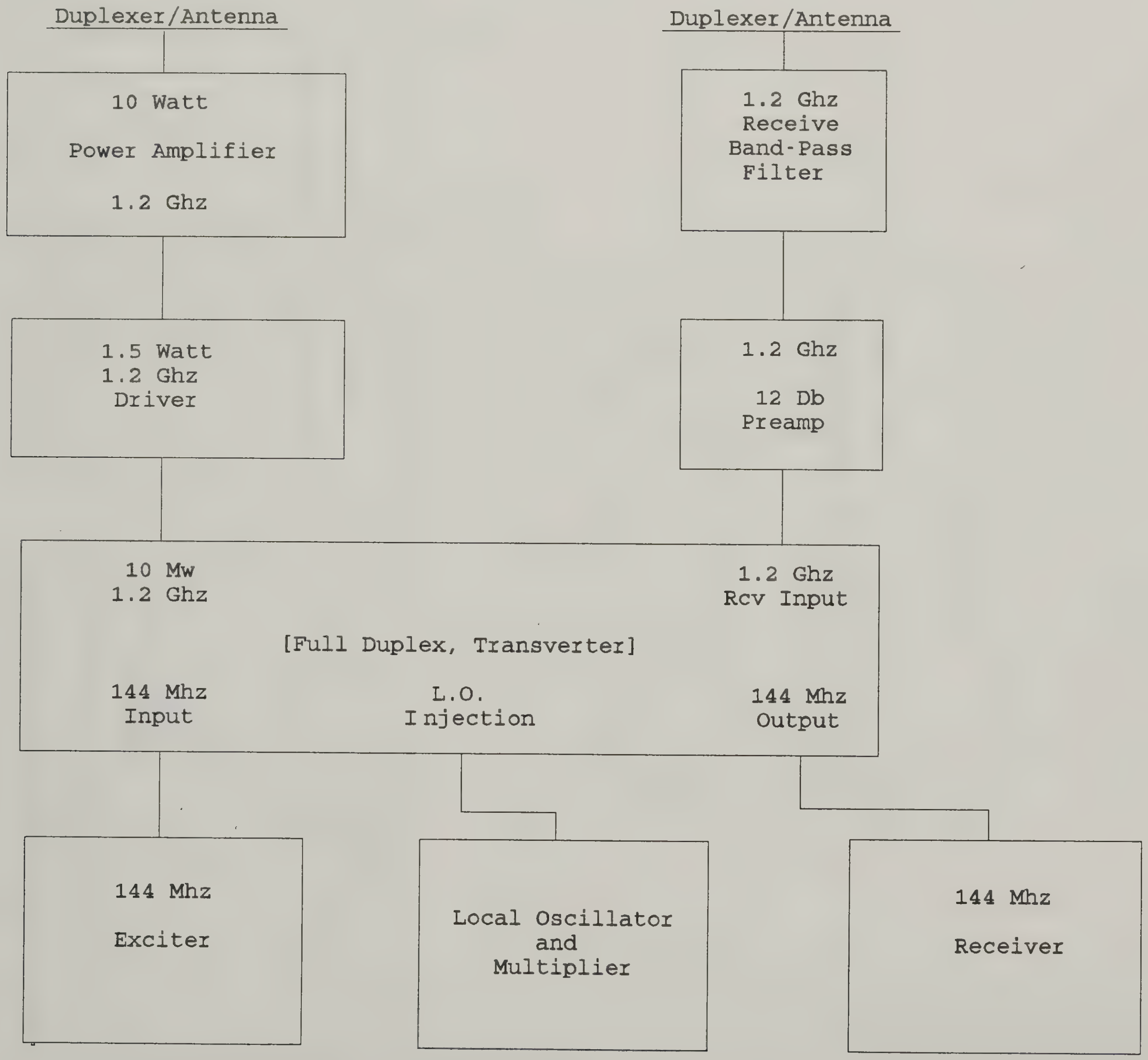
Heatsink Assembly

1.2 Ghz Repeater WA6RLV 03-16-92 J. Austin



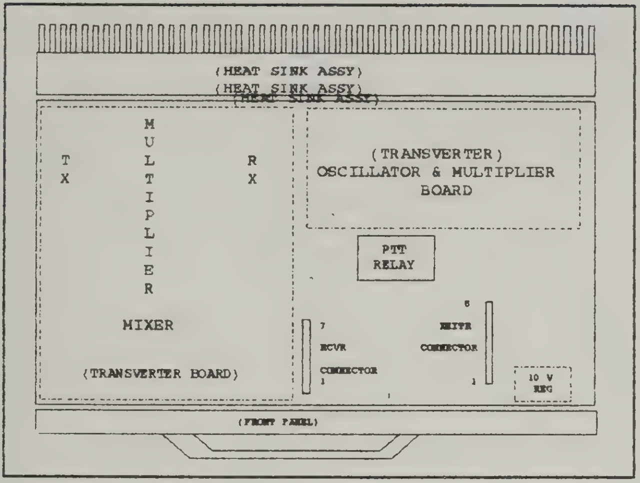
C.A.R.E. System 1.2 Ghz Repeater Configuration

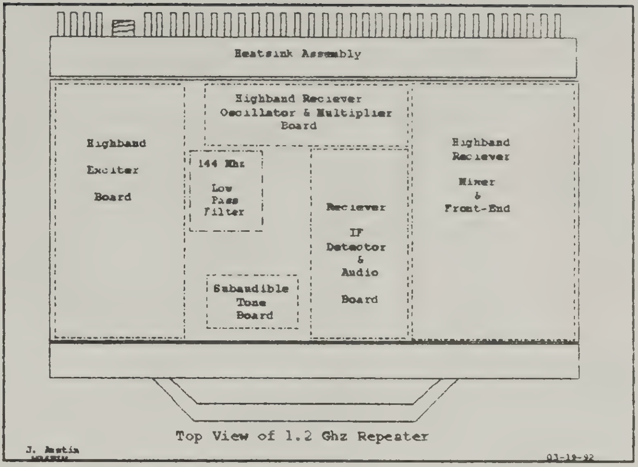
03-04-92 WA6RLV J. Austin



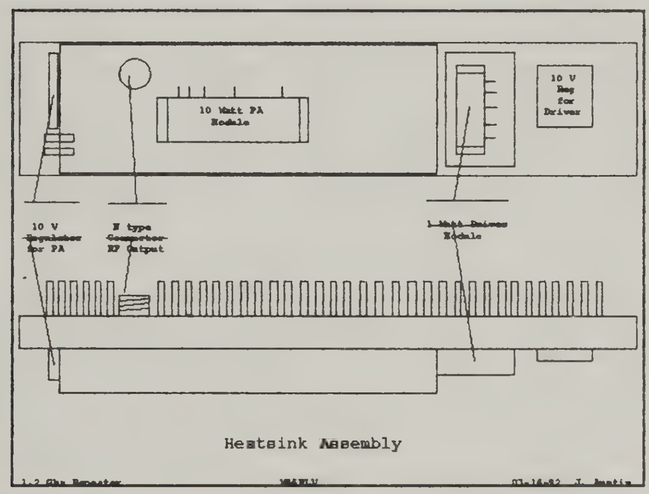
03-04-92
J. Austin
WA6RLV

1.2 Ghz Repeater
Block Diagram

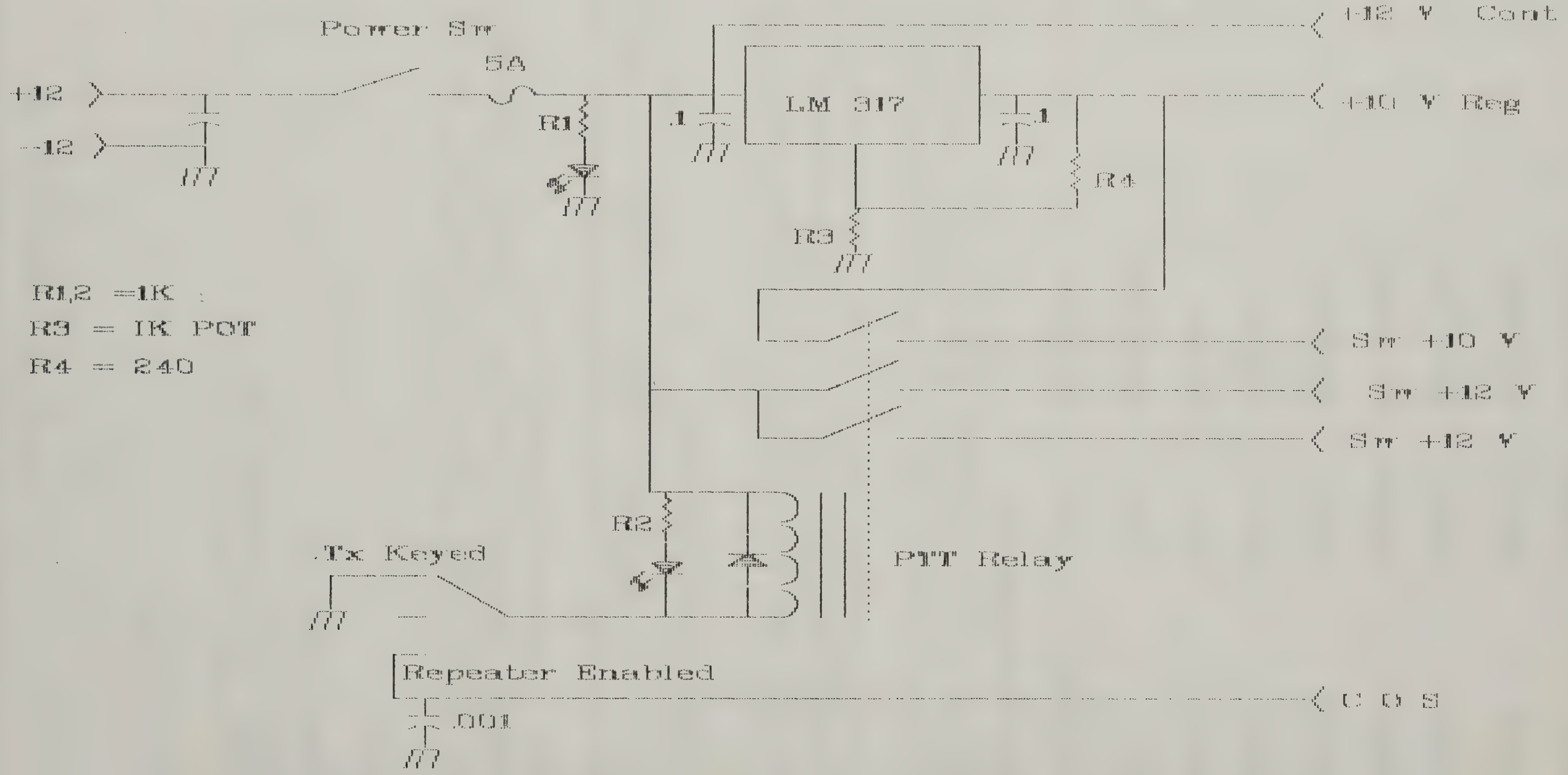




Top View of 1.2 Ghz Repeater



Heatsink Assembly



R1,2 =1K
R3 = 1K POT
R4 = 240

1.2 Ghz Repeater Power Supply & PTT

CONSORTIUM OF AMATEUR RADIO EXPERIMENTERS
6161 El Cajon Boulevard, Box 240
San Diego, CA 92115

December 21, 1993

Mr. Tom O'Hara, W6ORG
SCRRBA Technical Committee, 23cm
2522 Paxon Lane
Arcadia, California 91007

Dear Tom,

As you are aware, in the summer of 1991, **C.A.R.E.** began a project of building a network of 23cm. linked repeaters to serve San Diego and Imperial Counties. This was quite an ambitious undertaking which required total team effort. Collectively we have made a sizable investment in terms of time and money to equip each of our sites.

As you may recall, we pioneered converting the GE MASTR EXEC II's by equipping each radio with a DownEast Microwave Co. transverter. We initially had our share of quirks and problems related to receiver desense, PA instability, etc. I am pleased to report, difficulties related to the conversion process have been resolved.

I have enclosed basic conversion information for you to pass along to anyone who might want to explore this route in lieu of purchasing an ICOM repeater. Each site constructed represents an investment of approximately $2,000 (+/-) which includes a dual port controller, antenna system, interdigital filters, preamp, antenna splitter, duplexer, heliax/connectors, 420 link radio, etc.

The information contained in this letter is being provided to you so that you may update your records to reflect the present status of our system. We had to make a few adjustments from our original plan in order to successfully implement the system. The following table outlines our present system configuration:

FREQUENCY	**CALL**	**LOCATION**	**CHANGE**
1284.300	WV6H	Mt. San Miguel	No Change
1284.600	NF6E	Mt. Otay	Call
1284.600	N6CKS	Black Mtn.	No Change
1284.650	W6RHV	Mt. Palomar	Site/Call
1284.700	WB6DTR	Mt. Woodson	No Change
1284.700	WV6H	Tabletop Mtn.	Add Site
1284.750	WB6HHV	Mt. Soledad	No Change
1284.800	WA6RLV	Rattlesnake Pk.	Site/Call

All repeaters are operational as listed. CTCSS access tone is 91.5Hz. All repeaters are linked together to provide wide area coverage of San Diego and Imperial Counties.

We have abandoned our plans to utilize Toro Peak due to its' inaccessibility (snow) during the fall and winter months.

Cecil, WD6FZA (1283.175 Oat Mtn.) and Dan, NF6R (1283.375 Saddle Pk.) have joined our consortium and now are linked into our 420 MHz. hub located on Mt. Otay. Cecil will be placing a 23cm repeater at Santiago Peak. We anticipate having this site operational within 60 days. It is our desire to coordinate this repeater on 1284.900 MHz. Cecil will file a coordination request under separate cover. We are also planning to add a repeater at Santa Ynez during spring of 1994. At such time, we wish to duplicate either 1284.650 or 1284.800.

I have included a package consisting of updated system information sheets. As a final note, we have not experienced any problems from the WA6VLF ATV repeater located at Mt. San Miguel. Again, thank you for your cooperation in sanctioning us to occupy this portion of the band.

Also, please make note of my new address (see below) as I have moved since we last corresponded. **C.A.R.E.** maintains a post office box address for correspondence (see heading on page 1).

If you should have any questions, please feel free to contact me at (619) 455-8517 work, (619) 493-6271 pager/voice mail or (619) 449-2581 home.

Sincerely,
CONSORTIUM OF AMATEUR RADIO EXPERIMENTERS

Stu Hacken, WV6H

New home address:
10027 Trenchard Street
Santee, California 92071-1174

cc: SCRBBA P.O. Box
N6BVU, WA6LBV
WD6FZA, NF6R, NF6E, W6RHV, WB6HHV,
WA6RLV, N6CKS, WB6DTR

TE6IZA Jim
KE6IZC Nels
466-7359